Title: Surface Temperature Measurements

Brief Overview:

This lesson details how surface temperature may be used as a descriptor of an area's physical make-up. Students create a temperature map of a selected location by gathering surface temperature data over several days. In addition, since temperature data exhibits cyclic variation and both diurnal (day-night) and seasonal cycles are present, students fit a sine curve to a data set. If the students cannot obtain nighttime data, several monthly data sets are available from NOAA and are also included with this lesson. The NOAA data set will be used in this lesson to demonstrate the sine function.

Links to NCTM Standards:

- **Statistics**
  Students construct charts, tables, and graphs that summarize temperature data and use these graphs to verify a hypothesis.

- **Functions**
  Students model a surface area using temperature as a descriptor. Students analyze the cyclic nature of temperature data and fit a sine curve to the data.

Grade/Level:

9-12 grade

Duration/Length:

10 minutes per temperature measurement
2 hours for plotting, analysis and conclusions

Prerequisite Knowledge:

Students should have working knowledge of the following:

- Reading a thermometer
- Fahrenheit temperature scale

Objectives:

Students will:

- form a hypothesis.
- collect and organize data.
- graphically display the data.
- analyze and draw conclusions from the data.

Materials/Resources/Printed Materials:

- Thermometers
- Graph paper
- Rulers and measuring tape

Development/Procedures:

1. Tell students that there area many ways of describing a surface area; color, texture, solid, fluid etc. Ask students to think of descriptors for a surface area. Temperature also can be used as a descriptor of an area, since relative temperature will vary between surfaces. For example; on a sunny day cement will feel hotter to the touch than grass.

2. Ask students to form a hypothesis on what they think the temperature curve will look like for a day. The expected hypothesis is that temperature will increase in the morning, reach a peak around midday, and start decreasing in the afternoon.

3. Select an area that includes several different types of surfaces: cement, grass, bare soil etc. Assign each student a location in this area, preferably at even distances from each other but on different type of surface, i.e. students should not all be placed in a grassy area or all on a cemented area. Give each student a thermometer.

4 . Have students measure the temperature in their respective areas at least 3 times/day (morning, midday, afternoon). (If possible measure the temperature at even intervals throughout the day-night cycle.) Thermometers should be placed on the ground, and let stabilize for approximately 5 minutes before reading is taken. Students should not pick-up thermometers or shade them when taking the reading. Students should keep a log of their readings.

5. In addition to recording temperature students should note whether their area is in the shade or in the sun for each measurement.

6. Continue measurements for at least one week.

Graphing:

1. Have students draw a map of the area using the measuring tape and graph paper. Select a point where to start and measure distance to the next feature in the are. For example the CMST map was created by starting at the corner of the Arts&Tech building and the first measurement was to the line between grass and cement. Surface features should be labeled. (See Attachment 1).

2. Calculate average temperature for each site for each time of the day. (See Attachment 2 for data set collected during CMST 1998 session).

3. Assume that the average temperature is the same within approximately 10-20 feet from any one student.

4. Use color-coding to create a false color temperature map using the average temperatures for each time of day. The map can be created manually or by using a computer. (See Attachment 3).

5. Create a line graph displaying Temperature vs.Time of day. (See Attachment 4).

Analysis:

1. Students should evaluate the data and describe any differences between locations using the color-coded Temperature Map.

   Examples:
   Students at CMST discovered the following: Rachel and Rudell were placed only 7 feet apart, experiencing the same solar condition at every measurement time, their temperature readings differed with as much as 4 degrees Fahrenheit. The surface feature explains this difference. Rachel's thermometer was placed on the cement and Rudell's in the grass. Throughout the day, Mailaika, Dominic, and Alicia, whose thermometers where on the cement, read higher temperatures than their grass counterparts Rebecca, Kara and Toni. There was one exception Alicia read a higher temperature at 09:30 than Toni. Solar position explains this difference.

2. Using the Line graph, compare the hypothesis to the actual data. Does the data confirm the hypothesis?

   Examples:
   The graph for the CMST students indicates that their hypothesis (increasing temperatures until approximately midday, decreasing temperatures thereafter) is supported by the data in 4 cases. In 6 cases the data indicates that temperatures do not start declining until past the 2:30 p.m. reading. The most unexpected behavior is exhibited by Dymetrik's and Toni's data sets; both of these graphs show a decline in temperature between 09:30 and 11:30. Investigation showed that both sites were in the sun at 09:30 but ended up in the shade by 11:30.

   Sine curve

1. If students were able to gather data covering both day and night temperatures apply a sine curve to the data. If you do not have a complete day-night cycle use the data below to apply the function.

Temperature Data for Norfolk, VA

	Max	Min	Average	x	sin(x)	Temperature = 20.5 * Sin(x) +58.5
January	78	-3	38	-90	-1	38
February	81	8	45	-60	-0.866	41
March	88	18	53	-30	-0.5	48
April	97	28	63	0	0	59
May	100	36	68	30	0.5	69
June	101	45	73	60	0.866	76
July	103	54	79	90	1	79
August	104	49	77	120	0.866	76
September	99	45	72	150	0.5	69
October	95	27	61	180	0	59
November	86	20	53	210	-0.5	48
December	80	7	44	240	-0.866	41

Temperature = A * sin(x) + B

Where A = Amplitude = Max Average Temperature - Min Average Temperature / 2
= 79-38/2 = 20.5

To determine the phase of the curve i.e. the location along the x-axis of the zero crossing and minimum and maximum points of the curve, first find the coldest temperature. Then set the coldest temperature to coincide with -90 degrees, the point at which the quantity sin(x) is also minimum (-1). In this case January is the coldest and that data point corresponds to -90 degrees, (which is the same as +270 degrees).

sin(x) = 360 degrees / 12 months = 30 degrees/month

Increment with 30 degrees for each month, Jan -90 deg., Feb -60 deg., also.

B = Amplitude (A) + minimum average temperature = 20.5+38 = 58.5

See Attachment 5 for plots of the above data.

Performance Assessment:

The hypothesis formed by the students should be supported by the data and in the case that it is not, students should be able to come up with reasonable explanations to the discrepancies. Large unexplained discrepancies in the collected data should not be present.

Extension/Follow Up:

Graphing and analysis of other climate variables may be performed in a similar fashion.

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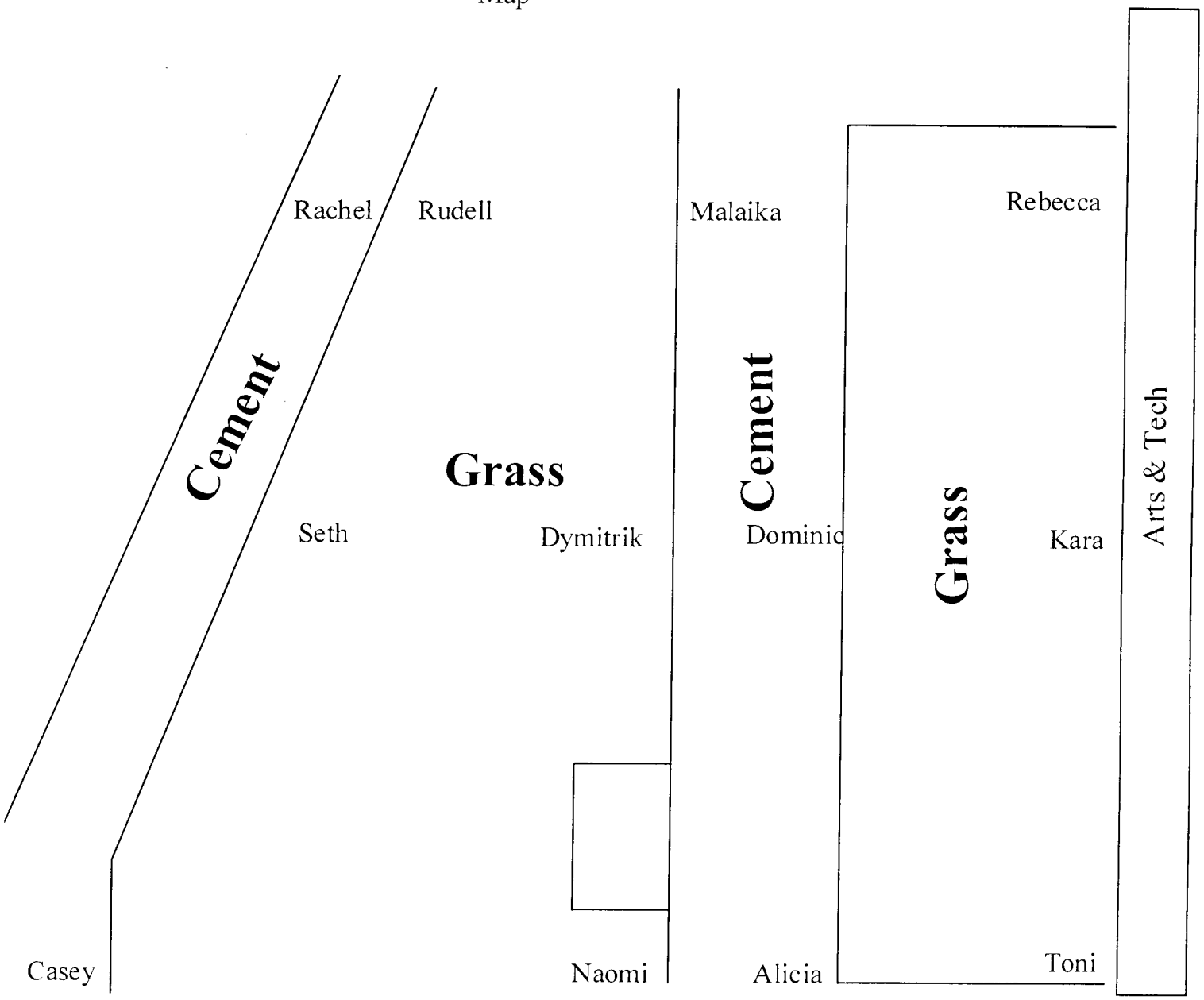
Attachment 1 - Site Map

Map



Kara	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	81	98	97	92
7/1/98	75	98	98	99
7/2/98	74	99	99	
7/6/98	81	93	93	
Average	78	97	97	96

Rebecca	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	82	92	90	85
7/1/98	72	94	82	74
7/2/98	76	94	82	79
7/6/98	78	82	86	
Average	77	91	85	79

Malaika	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	96	110	118	100
7/1/98	92	106	100	110
7/2/98	93	100	110	118
7/6/98	84	98		
Average	91	104	109	109

Dymetrik	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	98	90	110	98
7/1/98	98	92	110	108
7/2/98	96	86	104	106
7/6/98	108	88	96	
Average	100	89	105	104

Naomi	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	80	98	92	82
7/1/98	82	86	95	99
7/2/98	78	86	91	98
7/6/98	81	78	88	
Average	80	83	91	99

Seth	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	95	100	109	90
7/1/98	90	100	93	92
7/2/98	81	90	111	100
7/6/98	90	82	86	
Average	89	93	100	94

Rachel	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	100	104	110	101
7/1/98	92	102	110	104
7/2/98	91	108	105	96
7/6/98	90	85	90	
Average	93	100	104	100

Rudell	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	96	106	102	90
7/1/98	89	107	105	98
7/2/98	88	104	112	99
7/6/98	94	86	86	
Average	92	101	101	96

Casey	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98				
7/1/98	82	86	95	99
7/2/98	78	86	91	98
7/6/98	81	78	88	
Average	80	83	91	99

Dominic	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	100	104	110	102
7/1/98	92		105	105
7/2/98	91	107	100	110
7/6/98	100	90	100	
Average	96	100	104	106

Toni	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	91	80	92	90
7/1/98	88	78	88	80
7/2/98	88	78	80	82
7/6/98	94	78	86	
Average	90	79	87	84

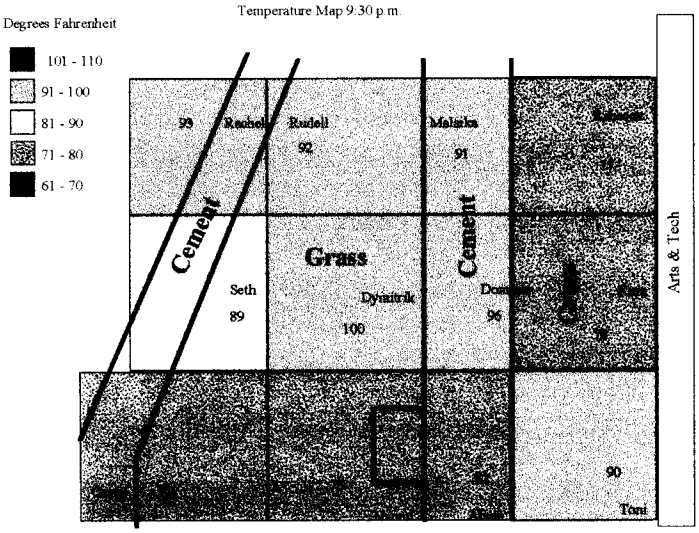
Alicia	**9:30**	**11:30**	**2:30**	**4:30**
6/30/98	87	89	82	88
7/1/98	86	78	88	76
7/2/98	80	77	76	79
7/6/98	75	90	77	
Average	82	84	81	81

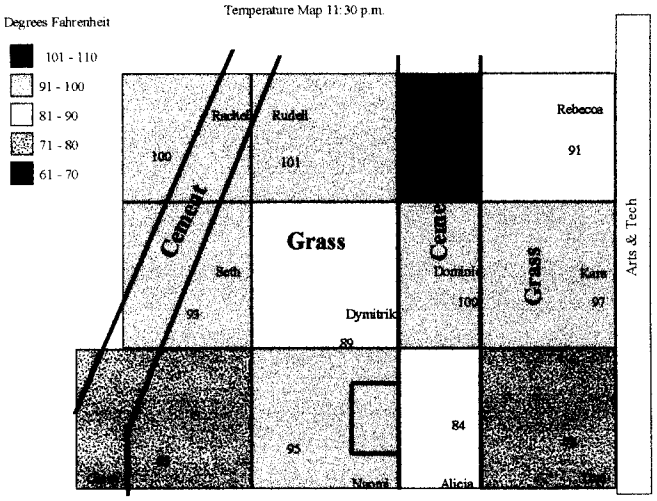
Attachment 2 cont.

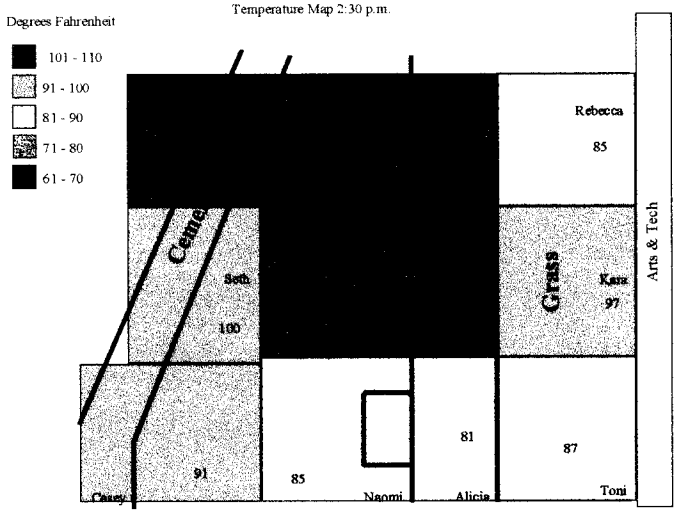
Average temperatures

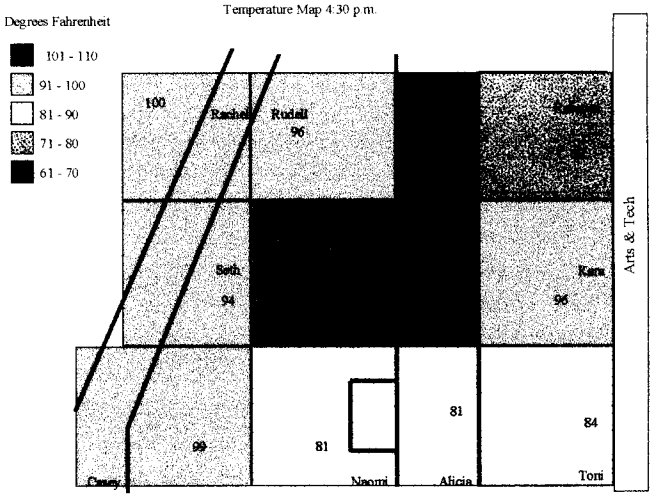
	9:30	**11:30**	**2:30**	**4:30**
Kara	78	97	97	96
Rebecca	77	91	85	79
Malaika	91	104	109	109
Dymetrik	100	89	105	104
Naomi	75	95	85	81
Casey	80	83	91	99
Dominic	96	100	104	106
Toni	90	79	87	84
Alicia	82	84	81	81
Rachel	93	100	104	100
Seth	89	93	100	94
Rudell	92	101	101	96

Attachment 3 - Temperature Map

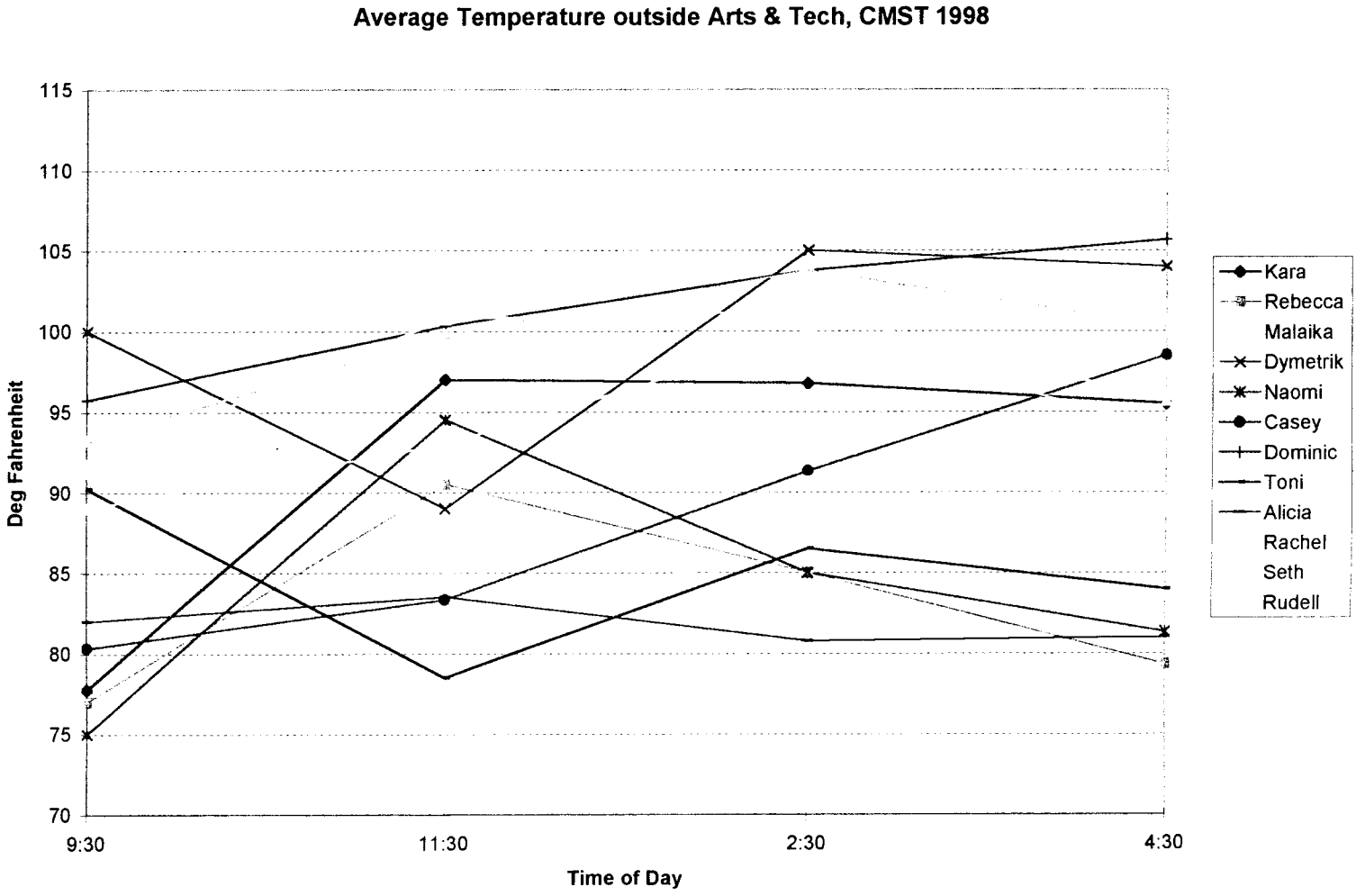








Attachment 4 - Plot of CMST 1998 data



Attachment 5 - Plot of Norfolk, VA Temperature data